



2-1-1970

Ecological Factors Affecting Lateral Distribution of Goldeye Hiodon Alosoides (Rafinesque), in the Little Missouri Arm, Lake Sakakawea, North Dakota

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ECOLOGICAL FACTORS AFFECTING LATERAL DISTRIBUTION OF GOLDEYE
Hiodon alosoides (Rafinesque), IN THE LITTLE MISSOURI ARM,
LAKE SAKAKAWEA, NORTH DAKOTA

by

STANLEY I. JOHANNES

Bachelor of Philosophy, University of North Dakota 1966

A Thesis

Submitted to the Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Science

Grand Forks, North Dakota

February
1970

This Thesis submitted by Stanley I. Johannes in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Committee under whom the work has been done.

John B. Owen

(Chairman)

James R. Kelly

Fred E. Lucins

William J. Anson

Dean of the Graduate School

Permission

Title ECOLOGICAL FACTORS AFFECTING LATERAL DISTRIBUTION OF GOLDEYE
Hiodon alosoides (Rafinesque), IN THE LITTLE MISSOURI ARM,
LAKE SAKAKAWEA, NORTH DAKOTA

Department Biology

Degree Master of Science

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Date January 18, 1970

ACKNOWLEDGMENTS

The author wishes to take this opportunity to thank my advisor, Dr. John B. Owen, for supervising and assisting me during the course of this project. I would also like to thank Dr. Fred Smeins and Dr. James Reilly for offering valuable criticisms of my manuscript and serving as members of my committee. In addition, I would like to acknowledge the Federal Bureau of Commercial Fisheries and the North Dakota Game and Fish Department for providing the financial support for the project. This study was supported by public law 88-309, the Commercial Fisheries Research and Development Act of 1964. Thanks is due also to Mr. Dale Henegar, Mr. William Hill, Mr. Selmer Enger, and Mr. Robert Patterson of the North Dakota Game and Fish Department for providing equipment and advice.

To Mr. Barney Schultz, Hydraulic Engineer, U.S. Army Corps of Engineers, Riverdale, N.D., for allowing me access to the records concerning sedimentation in Little Missouri Arm of Lake Sakakawea and for his help and assistance in their interpretation; to Mr. Robert Heib and Mr. Charles Wahtola, colleagues and fellow research associates who helped in the collection of all important field data, my sincere appreciation and special thanks are due.

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ABSTRACT

The lateral distribution of goldeye, Hiodon alosoides (Rafinesque) in Little Missouri Arm, Lake Sakakawea, North Dakota, was investigated during 1967 and 1968. This species, which is of commercial importance in Canada, is present in great abundance in Lake Sakakawea, yet is not commercially exploited in that body of water.

Experimental gill nets were fished from the surface at eight locations along the Little Missouri Arm to detect differences in goldeye populations along the length of the arm. A total of 7,191 fish were taken of which 6,536 or 90.80% were goldeye. Mesh selectivity data was recorded; 1½ inch mesh was the most effective. Total length, weight, and sex of all goldeye taken were recorded and scale samples collected. The length-frequency of the catch was plotted and the average rate of growth of six year classes was determined by examining scales from 567 fish. Seperate growth rates were calculated for male and female goldeye. Females averaged longer than males after the first year of life. Goldeye sex ratios favoring males increased gradually from stations 1 to 8. Increasing turbidity levels from stations 1 to 8 closely paralleled these increasing sex ratios indicating a possible correlation. Results also indicated that spring water temperatures affect both depth distribution and ripeness of goldeye.

Vertical water temperature, turbidity, and dissolved oxygen data were taken at each station to determine the presence or absence of density currents which have a profound affect on fish distribution in other reservoirs. Little evidence was found which suggested the existence of these currents.

INTRODUCTION

Goldeye, Hiodon alosoides (Rafinesque), are present in great abundance in Lake Sakakawea but have not been commercially exploited, although they are in demand in the Canadian market. Previous investigations in 1966 and 1967 have indicated that they were unmarketable due to their general small size. These investigations also indicated that the reservoir had a wide range of limnologic conditions resulting from the high inflow of silt. This produced a diminishing turbidity gradient and affected temperature in the upper reaches of the Little Missouri Arm. Therefore, the present study was designed to further investigate the effect of these limnological factors on the distribution of goldeye along this arm and to determine whether or not density currents, which in other reservoirs are known to profoundly affect fish distribution, were present.

LITERATURE REVIEW

There have been but few investigations concerned with the goldeye in the United States and Canada. Bajkov (1930) gave a brief history and statement concerning the economic status of the goldeye in the Province of Manitoba. However, records of goldeye production in Canada go back to 1876, but prior to 1900 they are erratic and misleading. Sizeable goldeye catches have been taken in Lake Winnipeg, with annual catches of over one million pounds taken between 1926-30 (Table 1). Since this time goldeye catches have been declining because of a constant demand for this fish as a source of food. Therefore, new production areas located in Alberta, Saskatchewan, Ontario and Quebec are being exploited to meet increased demands for smoked goldeye. Goldeye are taken commercially in Canada with gill nets of three and three quarters inch mesh set in short gangs perpendicular to the shoreline (Kennedy and Sprules, 1967). This technique has resulted in reduced populations because the species reaches commercial size before they mature sexually, thus heavy fishing efforts reduce breeding populations so that reproduction is inadequate to maintain the resource.

There has been a sustained commercial goldeye fishery in the Red Lakes, Minnesota, since 1916 where the peak annual take of 143,000 lbs. occurred in the years 1936-40 (Table 1). However, there has been a general reduction in catch since that time. The consensus has been that this reduction is due to increased fishing effort (Grosslein, 1954; Van Oosten and Deason, 1957; Grosslein and Smith, 1959). A similar

TABLE 1

AVERAGE ANNUAL GOLDEYE COMMERCIAL LANDINGS IN THOUSANDS OF POUNDS BY 5-YEAR INTERVALS SINCE 1901. A ZERO INDICATES LESS THAN 1,000 LBS. A DASH INDICATES THAT DATA ARE NOT AVAILABLE, USUALLY BECAUSE TOO FEW WERE PRODUCED TO WARRANT A SEPARATE CATEGORY AND THEY WERE RECORDED UNDER A "MISCELLANEOUS" HEADING. (AFTER KENNEDY AND SPRULES, 1967)

Years	Canadian					Total Canadian	U.S.A. ^b
	Quebec	Ontario	Manitoba	Sask.	Alberta		
1901-05	0	-	304	0	-	304	-
1906-10	0	-	649	12	-	649	-
1911-15	0	-	528 ^a	4	12 ^a	544 ^a	-
1916-20	0	-	558	4	3	567	67 ^a
1921-25	0	-	544	4	0	548	-
1926-30	0	-	1,011	6	1	1,018	31
1931-35	0	-	314	6	1	320	26
1936-40	0	-	446	8	0	454	143
1941-45	0	-	333	13	0	346	106
1946-50	0	54 ^a	142	0	81	253	36
1951-55	0	68	81	0	48	197	4
1956-60	0	37	75	10	112	234	49
1961-65	7 ^a	26	72	23	58	180	13

^a Average based on less than 5 years.

^b Almost entirely from Red Lakes, Minnesota.

reduction of goldeye population in confined areas of Fort Peck Reservoir, Montana has been accomplished by intensive and continuous experimental netting (Cooper, 1967). In 1967 a small commercial fishery took large numbers of goldeye from other areas of the reservoir; however, due to their small size they were sold at less than the market price.

Studies of age and growth of goldeye have been made by Kennedy and Sprules (1967) in Canada; by Eddy and Carlander (1942), Grosslein (1954), and Grosslein and Smith (1959) in Montana; by Martin (1952) in Oklahoma, and by Heib (1968) in the Little Missouri Arm of Lake Sakakawea, North Dakota. Differential growth rates between male and female goldeye have been reported by Martin (1952) and Grosslein and Smith (1959).

Hinks (1943) reported that unlike most other fish, sexually mature goldeye do not spawn annually. Battle and Sprules (1960) described the eggs and early developmental stages of goldeye ova; ova are bathypelagic, or semibouyant. Considerable variance in sex ratios within different populations of goldeye have been found (Table 2) and Heib (1968) reported that the proportion of gravid females in surface waters increased with temperature.

Surveys by the North Dakota Game and Fish Department using bottom sets indicated the relative abundance of goldeye in Lake Sakakawea to range between 26.38 percent in 1964 to 36.40 percent in 1966 (Duerre, 1965; Hill, 1966, 1967). Peterson (1967) used a vertical net suspended from the surface and found that goldeye represented 53.28 percent of the catch.

Peterson (1967) studied the vertical distribution of goldeye and

reported the species to be nocturnal, surface feeders during the summer months. Cooper (1968) reported that the vertical distribution of goldeye in Fort Peck Reservoir appeared to be affected by water temperature (Table 3). As the reservoir cools the vertical distribution of goldeye is altered and they move into deeper water.

Density currents are flowing solutions or mixtures of gases and liquids which differ in density from a main body of enclosing fluid by virtue of difference in temperature or concentration of solute (Menard and Ludwick, 1951). According to Daly (1936) and Johnson (1939), a turbidity current in a lake or reservoir is a special type of density current consisting of sediment laden water inflowing from a river. Therefore, depending on their temperature they may, 1) remain on the surface because they are less dense than the reservoir water, i.e., an overflow; 2) flow through it at a similar temperature density, i.e., an interflow; 3) flow along the bottom if they are denser than any of the reservoir water, i.e., an underflow.

The density of turbidity currents increases from top to bottom (Menard and Ludwick, 1951). The coarser particles are rapidly deposited at the point of inflow whereas the finer particles are carried for considerable distance into a reservoir before finally coming to rest on the bottom (Fig. 1). These currents may travel long distances and are difficult to disperse. Consequently, they are effective transporting agents. In Lake Mead, Colorado, with a channel gradient of 5 feet per mile, underflowing turbidity currents transport sediment some 70 miles (Grover and Howard, 1938).

Although Auerbach (1926) first intensively studied the

TABLE 2

COMPARISON OF SEX RATIOS OF GOLDEYE TAKEN IN OTHER AREAS

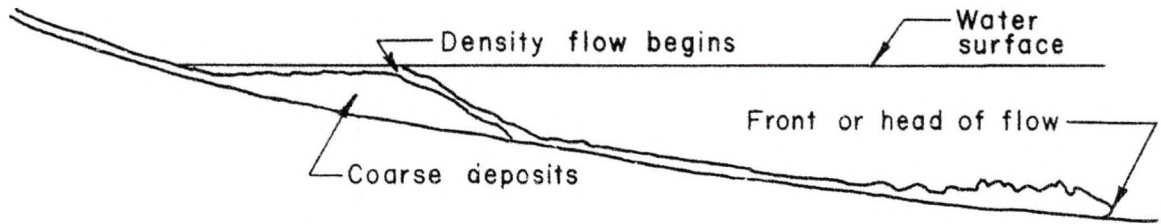
Location	No. Specimens	% Males	% Females
Saskatchewan Delta (Kennedy and Sprules, 1967)	2,087	26.7	73.3
Red Lake, Minn. (Grosslein and Smith, 1959)	389	56.0	44.0
Lake Texoma, Oklahoma (Martin, 1952)	889	27.9	72.1
Fort Peck Reservoir, Mont. (Hill, 1965)	450	29.1	70.9
Missouri River Above Fort Peck Reservoir, Montana (Hill, 1965)	415	59.3	40.7
Teton River (Tributary of Fort Peck Reservoir, Montana) (Hill, 1965)	812	53.1	46.9

TABLE 3

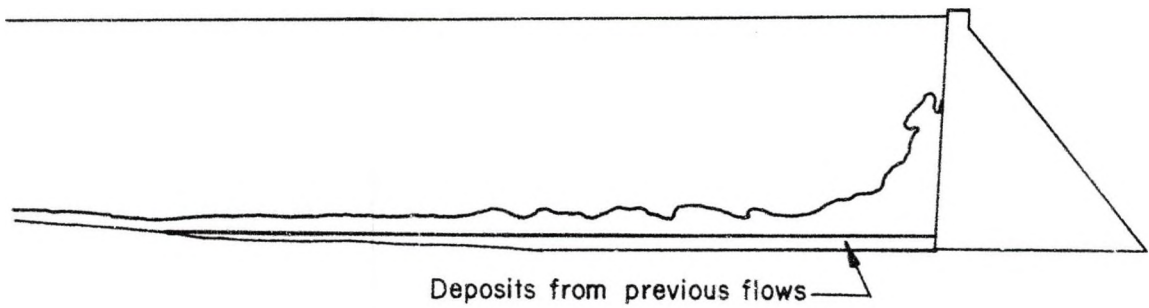
VERTICAL DISTRIBUTION OF GOLDEYE IN FORT PECK RESERVOIR (FALL 1967).^a

	Number of Goldeye			
Date and Temp. (C) ^b	Nov. 20 (9.0)	Nov. 24 (7.8)	Dec. 5 (6.6)	Dec. 16 (4.5)
Depth in Feet				
0-8	48	66	18	1
8-16	28	56	46	6
16-24	7	22	51	26
24-32	1	4	40	25
32-40	0	2	40	44

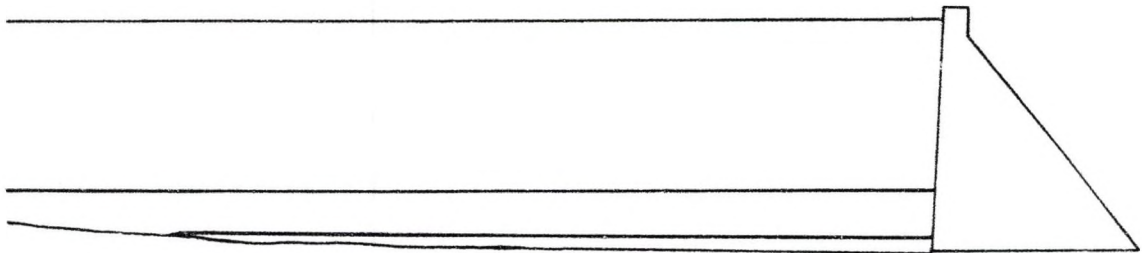
^aAfter Cooper, 1968.^bTemp. taken from 2½ ft. depth.



UPON ENTERING RESERVOIR MUDDY STREAM BECOMES TURBID DENSITY FLOW



HEAD OF FLOW BREAKS ON DAM



FLOW COMES TO REST AS SUBMERGED MUDDY LAKE

FIG. 1. Life history of a density flow (After Bell, 1942).

effect of density currents on aquatic environments in Germany, it was not until the late 1930's that investigations of reservoirs in the United States were undertaken. By investigating chemical and physical characteristics such as turbidity, low alkalinity and dissolved oxygen, Wiebe (1939) detected the presence of density currents. Subsequent laboratory studies by Bell (1942) have substantiated Wiebe's findings.

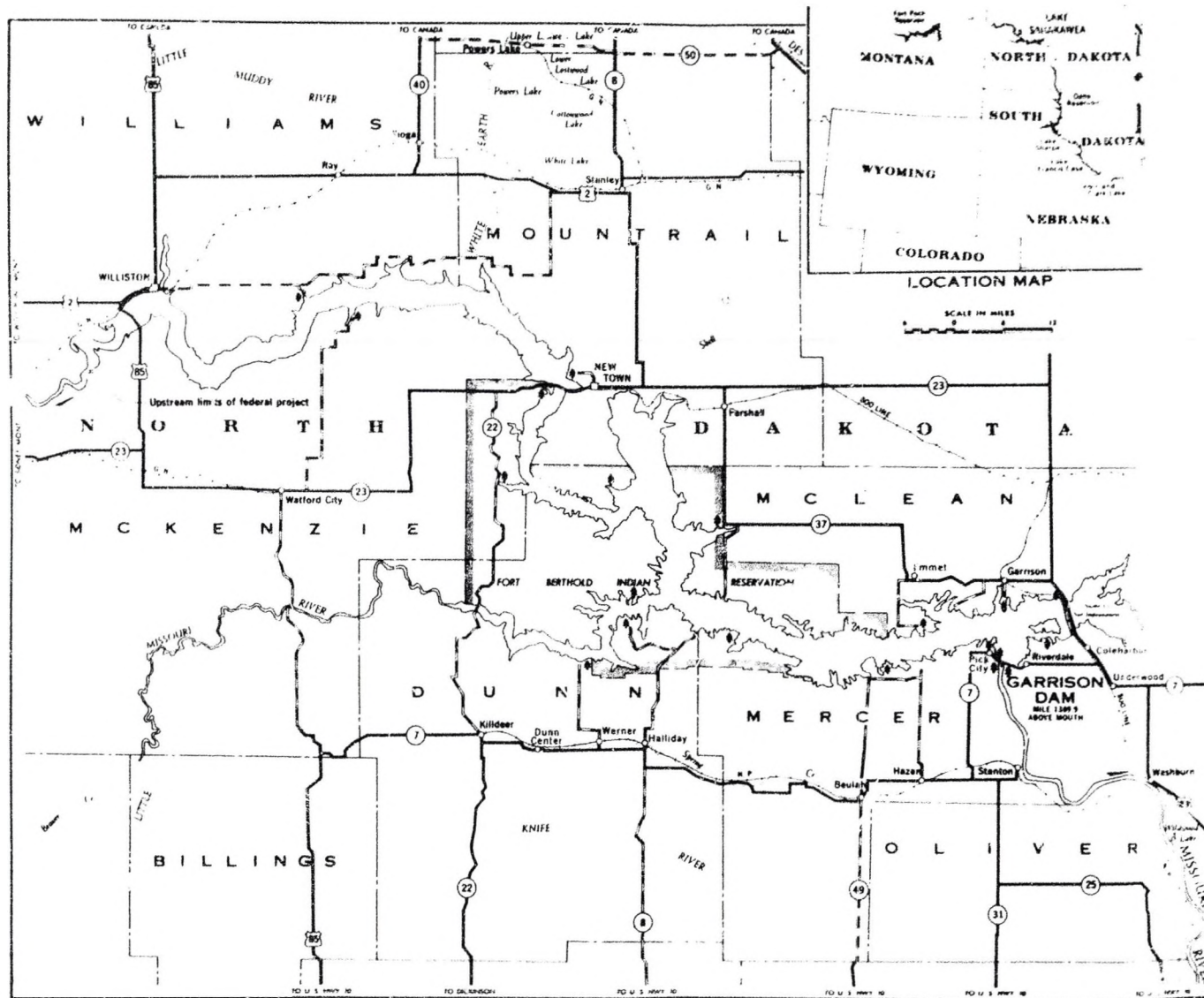
DESCRIPTION OF THE AREA

Lake Sakakawea, formerly Garrison Reservoir, was created by closing Garrison Dam at Riverdale, northwestern North Dakota, in April 1953 (Fig. 2). The dam creating this impoundment was constructed by the U.S. Army Corps of Engineers primarily for flood control and irrigation, with recreation, navigation and production of hydro electric power as secondary objectives. This reservoir, the largest of the main-stem Missouri impoundments, contains 24,500,000 acre-feet of water and has a surface area of 326,000 acres at capacity (Neel, 1963). It is 200 miles long with an average width of three miles, a maximum depth of 180 feet and a shoreline of approximately 1,600 miles (Duerre, 1965).

The Little Missouri River, a major tributary of Lake Sakakawea, originates in Crook County, Wyoming, and flows northeast through western North Dakota. It drains an area of about 9,500 square miles with a channel gradient averaging about 4.6 feet per mile (U.S. Dept. of Interior, 1951). In many years there is little, if any flow during the winter months of January and February. These negligible winter discharge rates permit the existence of only those species of fish which can tolerate low oxygen concentrations (U.S. Dept. of Interior, 1951).

According to the Corps of Engineers, the Little Missouri River has a silt concentration of more than twice that of the Missouri River at Kansas City, Missouri (U.S. Dept. of Interior, 1951). Silt loads average approximately 7,630 ppm. However, the Geological Survey has reported silt concentrations of 20,100 ppm (Love, 1957).

Fig. 2 Lake Sakakawea, North Dakota



The Little Missouri Arm, which varies in both width from $3/4$ to $1/16$ of a mile and in depth from 65 to 5 feet from the river reservoir confluence to Lost Bridge respectively, was chosen as the site of this investigation. The badlands, an erosional landscape, are well developed along the arm and its numerous tributaries. Because of irregular shorelines there are many small bays in which aquatic vegetation in the littoral zone is practically non-existent due to fluctuating water levels. Erosion and runoff from the soft clays and sands of the region contribute enormous quantities of silt to this reservoir arm.

The climate of the Little Missouri Valley varies from semiarid to subhumid and has an average annual precipitation of approximately 16 inches, which includes some 25-30 inches of snow (Bavendick, 1952). Seventy-five percent of this precipitation occurs between April and October. June is the wettest month; however, periods of below average precipitation are common. The average date of the first killing frost of Autumn is September 20th and freeze-up occurs late in November (U.S. Dept. of Interior, 1951). Ice-out occurs late in April; in 1967 this was on the 17th of April (Heib, 1968).

METHODS AND MATERIALS

This investigation was carried out between 1 July and 7 September, 1967, and between 15 April and 30 June, 1968. Eight stations, i.e., 1 to 8, were established $2\frac{1}{2}$ to 5 miles apart along the Little Missouri Arm of Lake Sakakawea, with the greater distances separating those stations closer to the confluence of the Little Missouri and Missouri Rivers. Stations 1 through 8 were sampled biweekly in 1967 and only stations 1 through 6 in 1968 (Fig. 3) because water levels ten feet below those of 1967 made it impossible to sample stations 7 and 8 (Fig. 4). A vertical series of water temperatures were taken at five foot intervals beginning $2\frac{1}{2}$ feet below the surface at each station using a hydrographic thermometer, model Ft3 (Applied - Research/Austin Inc.). Water samples for the determination of dissolved oxygen and turbidity were taken with a one liter Kemmerer water bottle. A $\frac{1}{2}$ liter transparent Foerst sampler was used to detect turbid layers of water. Water samples were analyzed with a Hach Kit model DR-2834 B. Dissolved oxygen was recorded in parts per million and turbidity in Jackson Turbidity Units (J.T.U.).

Experimental gill nets, 125 by 5 feet, constructed of five 25-foot lengths of $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, and $1\frac{3}{4}$ inch bar mesh, respectively, were fished from the surface and the bottom. The use of these mesh sizes favored catching fish of all sizes. Nets were set in the morning and hauled 24 hours later. The size of goldeye caught in each mesh size during each set was recorded for analysis of mesh selectivity.

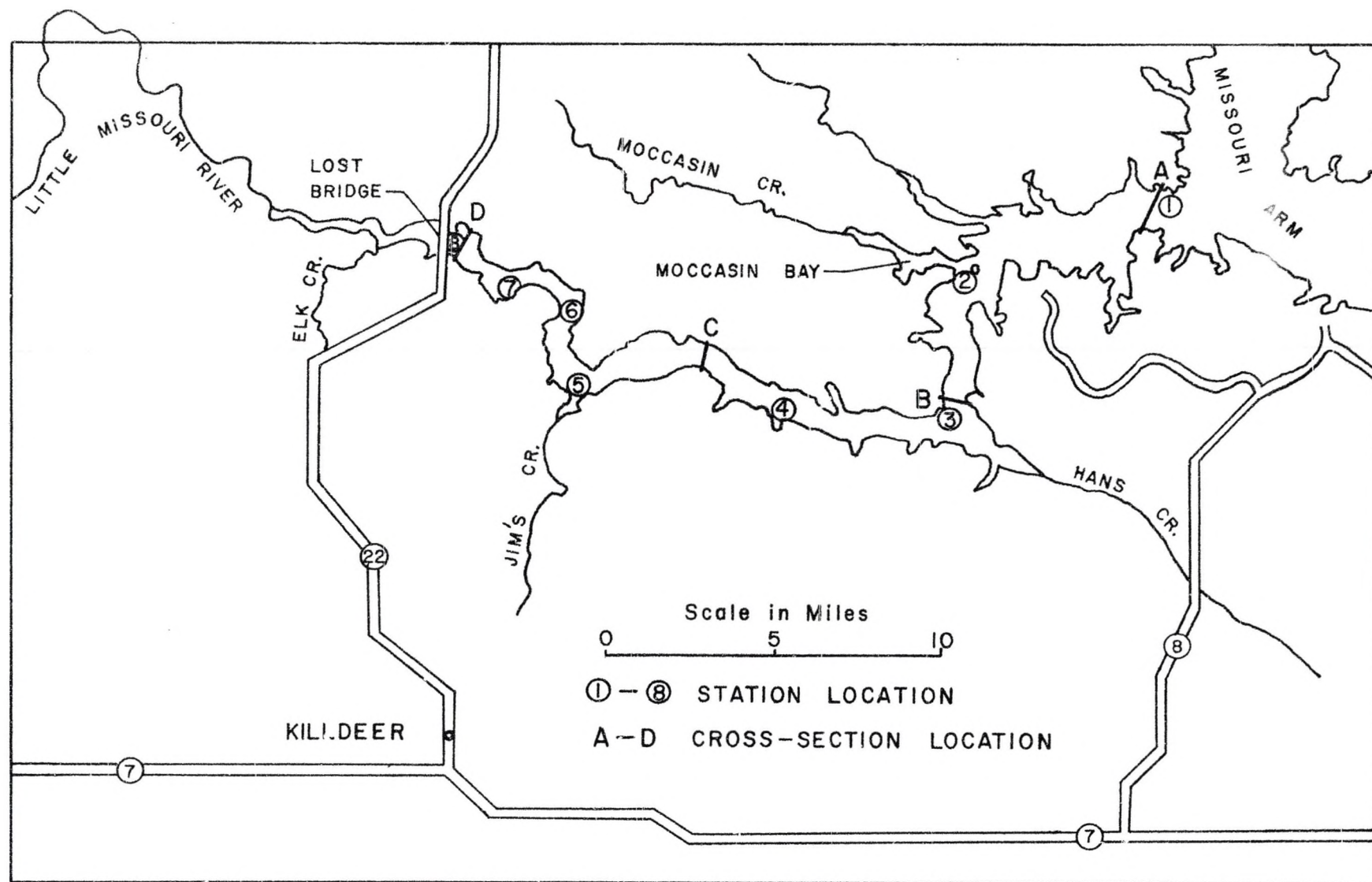


FIG. 3. Map of Little Missouri Arm showing station and cross section locations.

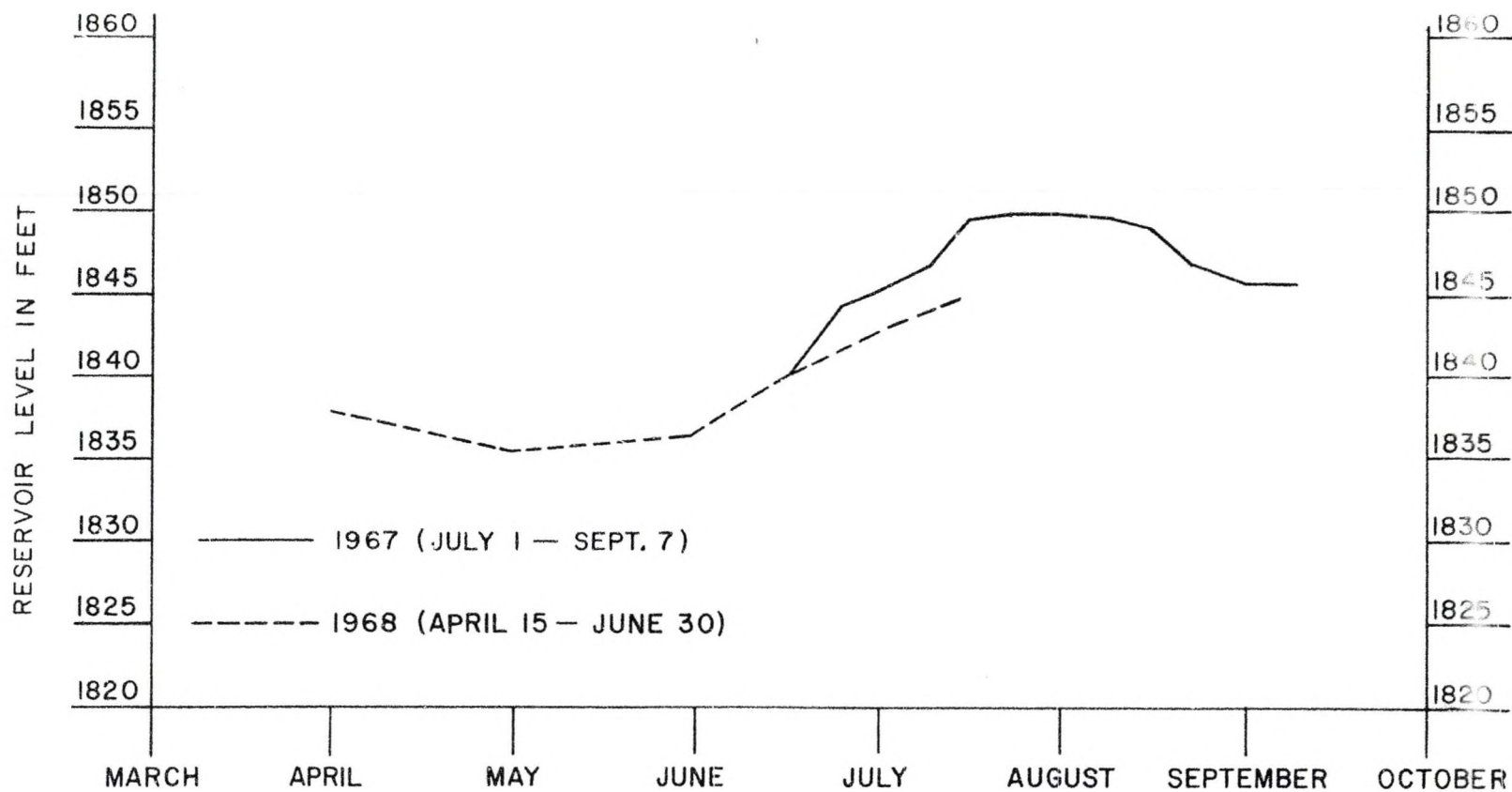


FIG. 4. Lake Sakakawea water levels 1967-68.

Goldeye was the primary species investigated. However, length, weight, and sex of all species captured were recorded. Measurements were taken as quickly as possible to avoid shrinkage from exposure. As fish were removed from the net they were covered by moist burlap to minimize water loss. Weights were taken on a spring balance (Hanson Dietic Scale, Model 1460) and recorded to the nearest gram; total length was measured to the nearest tenth of an inch. Scale samples were taken from goldeye from an area between the dorsal fin and lateral line of the left side (Rounsefell and Everhart, 1953). Scale impressions were made on cellulose acetate strips with a roller press following the technique described by Smith (1954). Impressions were projected and magnified by means of a Bausch and Lomb microprojector. Paper strips were superimposed upon these images and scale length and point of interception of each annulus was marked. A straight line relationship between scale and body length was assumed. Nomographs, using a correction factor of 1.28 inches, were used to compute the average annual growth increments for each year class.

Sex of all goldeye were determined by the inspection method of Heib (1968) and were recorded. All fish that could not be sexed by visual inspection were dissected to determine sex. Ratios of males to females at each station were calculated.

During spring field investigations in 1968, female goldeye were examined for spawning condition as determined by the ease by which their eggs could be stripped. In this way, beginning and progress of spawning activity could be recorded and related to ambient water temperatures.

RESULTS

Seventy-one hauls of a 12 by 5 foot experimental gill net yielded a total of 7,191 fish, of which 6,536 or 90.80 percent were goldeye (Table 4). The catches of goldeye from the 40 settings in 1967 and the 30 settings in 1968 are given in Table 5. The 4,336 and the 2,153 measureable goldeye captured during 1967 and 1968, respectively, are grouped by length into one inch size groups. Tables 6 and 7 give the catches of goldeye by size groups for each sampling period. Tables 15 through 19 and 20 through 24 (Appendix A) give similar data for each station in 1967 and 1968 respectively. In 1967 females were almost twice as abundant as males in the catches at stations 1, 2, and 3 while males were more abundant in the catch at stations 6, 7, and 8 (Table 8).

Mesh selectivity data was randomly recorded on 3,709 goldeye during 1967 and 1968 and are presented in Table 9. Of the five mesh sizes used, the most effective for taking goldeye was the $1\frac{1}{4}$ inch mesh. However, the $1\frac{1}{2}$ inch mesh captured those of the largest average length, 11.47 inches.

The depth distribution of 367 goldeye in the spring of 1968 appears to be affected by an increase in water temperature because as the water warmed there was an increase in the numbers of fish taken near the surface and a concomitant decrease in numbers taken near the bottom (Table 10). In addition, a greater number of ripe females were taken at locations having warmer water temperatures (Table 11).

The length-frequency distribution of 6,489 goldeye is presented in

TABLE 4

*CATCH OF FISH BY SPECIES TAKEN ALONG LITTLE MISSOURI ARM,
LAKE SAKAKAWEA, NORTH DAKOTA, 1967-68.

Species	No. Caught	Percent of Total No.
Goldeye	<u>Hiodon alosoides</u> (Rafinesque) 6,536	90.80%
Channel Catfish	<u>Ictalurus punctatus</u> (Rafinesque) 353	4.90
Sauger	<u>Stizostedion canadense</u> (Smith) 76	1.06
Yellow Perch	<u>Perca flavescens</u> (Mitchill) 58	.81
White Crappie	<u>Pomoxis annularis</u> (Rafinesque) 34	.48
Walleye	<u>Stizostedion vitreum</u> (Mitchill) 30	.42
River Carpsucker	<u>Carpoides forbesi</u> Hubbs 29	.40
Black Bullhead	<u>Ictalurus melas</u> (Rafinesque) 28	.39
Northern Pike	<u>Esox luscus</u> Linnaeus 18	.25
Carp	<u>Cyprinus carpio</u> Linnaeus 17	.24
Golden Shiner	<u>Notemigonus crysoleucas</u> (Mitchill) 10	.14
Freshwater Drum	<u>Aplodinotus grunniens</u> Rafinesque 6	.08
Northern Redhorns	<u>Moxostoma auriolum</u> (Lesueur) 4	.05
Bigmouth Buffalo	<u>Ictiobus cyprinellus</u> (Valenciennes) 2	.03
	7,191	100.00%

*Fishes taken with 125 by 5 foot gill nets.

TABLE 5

GOLDEYE CAPTURED AT EACH STATION DURING EACH SAMPLING
PERIOD 1967 and 1968.

1967	Station No.							
	1	2	3	4	5	6	7	8
July 1-15	78	54	123	132	109	154	110	127
July 16-30	71	80	92	40	153	183	103	129
Aug. 1-15	69	70	100	100	196	197	72	120
Aug. 16-30	101	46	88	72	69	112	185	129
Sept. 1-15	65	80	95	77	92	80	218	117
Total (1967)								4,376
1968								
April 15-30	1	3	6	32	43	19	Not Sampled	
May 1-15	37	60	23	66	183	29	"	"
May 16-30	45	64	64	160	164	115	"	"
June 1-15	52	2	59	150	166	62	"	"
June 16-30	27	27	92	135	229	45	"	"
Total (1968)								2,160
Grand Total (1967 & 1968)								6,536

TABLE 6

INCH CLASS TOTALS OF GOLDEYE BY SAMPLING PERIOD FOR 1967.

	Inch Classes									
	4	5	6	7	8	9	10	11	12	13
July 1-15	0	0	4	110	188	77	248	281	57	2
July 16-31	0	0	1	104	159	51	218	248	40	2
Aug. 1-15	3	1	3	42	204	63	208	346	49	0
Aug. 16-31	1	1	2	12	140	87	192	301	59	5
Sept. 1-15	0	0	2	16	112	96	174	336	88	3
Totals ^a	4	2	12	284	803	374	1,040	1,512	293	12

^aGrand total measured during 1967 - (4,336 goldeye)

TABLE 7

INCH CLASS TOTALS OF GOLDEYE BY SAMPLING PERIOD FOR 1968

	Inch classes										
	4	5	6	7	8	9	10	11	12	13	14
April 15-30	0	0	0	0	0	4	16	56	29	2	0
May 1-15	0	0	0	0	3	4	56	252	72	7	1
May 16-30	0	0	0	1	1	10	68	372	143	13	2
June 1-15	0	0	1	0	2	10	88	287	97	7	0
June 16-30	3	0	1	3	5	10	87	332	104	10	0
Totals	3	0	2	4	11	38	315	1,293	445	39	3

TABLE 8

SEX RATIOS OF LITTLE MISSOURI ARM GOLDEYE DURING THE PERIOD
JULY 1 TO SEPT. 15, 1967.

Station No.	No. Fish	No. Males	No. Females	Percent Males	Percent Females	Male/Female Ratio
1	345	124	221	35.9	64.1	1:1.78
2	291	105	186	36.1	63.9	1:1.77
3	307	110	197	35.8	64.2	1:1.79
4	291	134	157	46.0	54.0	1:1.17
5	488	265	223	54.3	45.7	1:0.84
6	435	216	219	49.6	50.4	1:1.01
7	615	370	245	60.2	39.8	1:0.66
8	609	372	237	61.1	38.9	1:0.64
Totals	3,381	1,696	1,685	50.2	49.8	1:0.99

TABLE 9

GILL NET MESH SELECTIVITY OF LITTLE MISSOURI ARM GOLDEYE*

Mesh size (inches)	No. of goldeye	Range in inches	Average length (inches)
$3/4$	545	3.1-12.6	10.17
1	962	4.1-13.1	10.52
1 $1/4$	1,327	4.0-13.6	11.11
1 $1/2$	756	4.1-13.7	11.47
1 $3/4$	119	7.1-13.8	11.33

* Goldeye taken with a 125 by 5 ft. floating net

TABLE 10

GOLDEYE CAPTURED AT SURFACE AND BOTTOM IN LITTLE MISSOURI ARM (SPRING 1968).^a

		Number of Goldeye				
Date and Temp. (C) ^b		April 21 (4.5)	May 6 (7.0)	May 17 (9.0)	June 5 (15.5)	June 19 (16.0)
Depth	Upper 5 feet	1	21	64	59	90
	Bottom 5 feet	38	35	20	22	17

^a Station number three^b Temps. taken at 2 1/2 ft. depth

TABLE 11
RELATIONSHIP OF WATER TEMPERATURE TO SPAWNING
CONDITION OF GOLDEYE (SPRING 1968).

Station No.	No. of Females	No. Ripe Females	Percentage Ripe Females	Water Temp. (C)
April 15-30				
1	1	0	0	3.0
2	1	0	0	4.0
3	5	0	0	4.5
4	20	8	40	6.0
5	26	16	61	8.0
6	11	6	54	8.0
May 1-15				
1	27	12	44	6.5
2	28	11	39	6.0
3	12	6	50	7.0
4	34	17	50	8.0
5	93	60	64	8.0
6	13	11	85	9.0
May 16-30				
1	26	16	61	7.0
2	35	9	26	7.5
3	48	14	29	9.0
4	84	58	69	11.0
5	88	48	66	11.0
6	56	44	79	16.5
June 1-15				
1	36	13	36	15.0
2	2	1	-	15.0
3	34	14	41	15.5
4	87	52	60	14.5
5	57	45	79	15.0
6	35	32	91	15.5
June 16-30				
1	21	1	5	14.5
2	15	4	27	13.5
3	50	17	34	16.0
4	65	28	43	18.0
5	103	88	85	17.5
6	32	25	79	18.0

Figure 5. Eleven inch fish account for 43 percent of those sampled, thus establishing it as the dominant inch class.

To estimate body lengths at various age periods from scale measurements, a regression of body and scale lengths of fish at time of capture was employed. Scale radii and body lengths of 567 goldeye were used to describe a straight line regression for the equation $y = a + bx$; where y = total length ; a = constant ; b = a constant ; x = scale radius. The regression line calculated to describe the body - length / scale - length relationship was expressed by the formula : $y = 1.28 - 1.25 (x)$. Growth estimates at the various annuli were directly proportional to those described in a nomograph described by Carlander and Smith (1944); 1.28 inches was used as a starting point (Fig. 6).

Approximately ten scales per sampling period were examined to determine time of annulus formation. Newly formed annuli were first observed on the scales of fish collected June 1, 1968. Seven fish taken June 23, 1968, had all formed the annulus for that year.

The annuli of goldeye scales collected in 1968 revealed six year classes to be present. Of 567 fish examined, 30 were in age group I ; 115 in age group II ; 132 in age group III ; 190 in age group IV ; 90 in age group V ; and 10 in age group VI (Table 12). The average lengths of the age groups were : 5.1 inches at age I ; 7.9 inches at age II ; 9.7 inches at age III ; 10.8 inches at age IV ; 11.4 inches at age V ; and 11.9 inches at age VI, respectively. Mean annual growth increments of 5.1 inches to age I ; 2.8 inches to age II ; 1.8 inches to age III ; 1.1 inches to age IV ; .6 inches to age V ; and .5 inches to age VI indicate a decline in growth rates as goldeye age. The average total

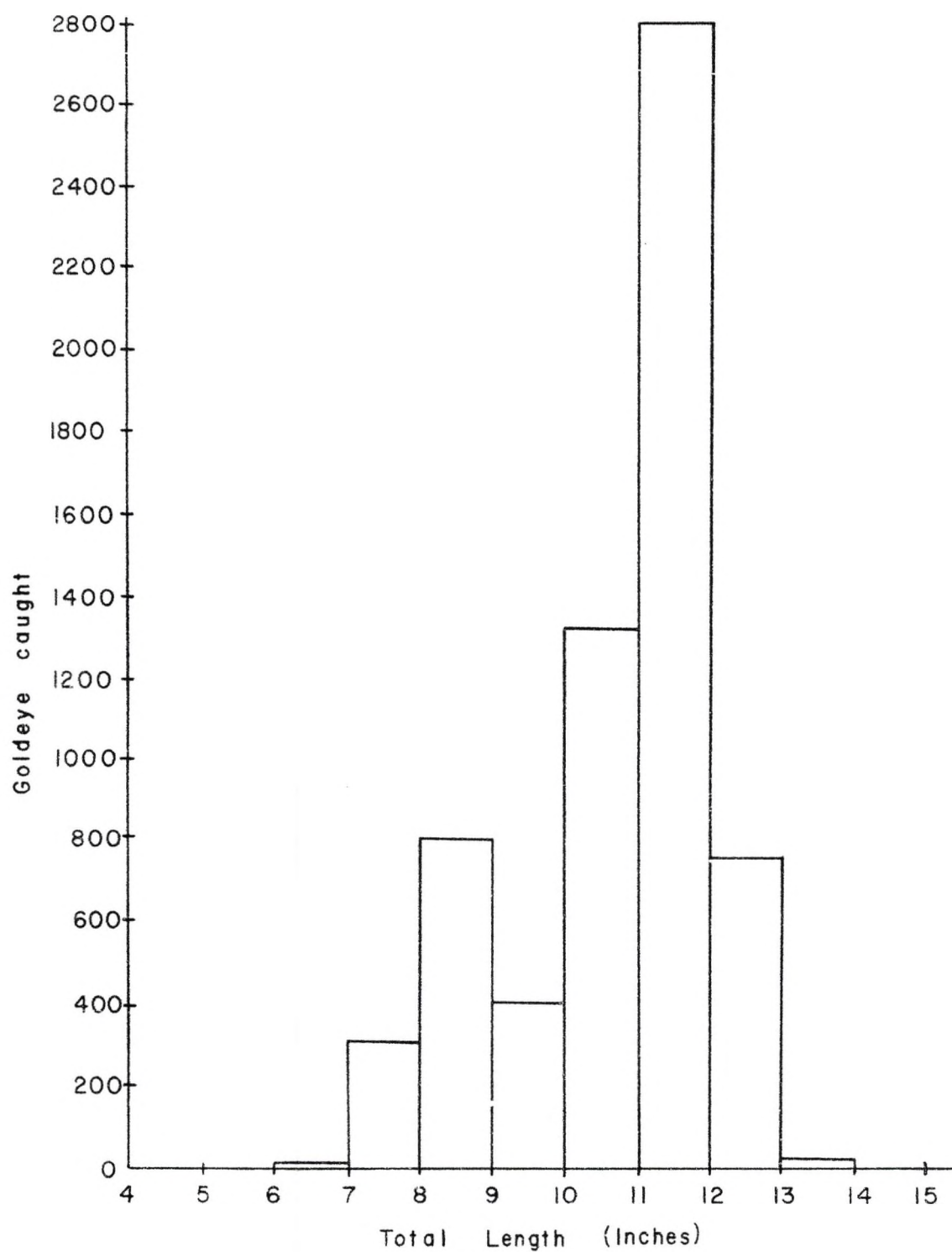


FIG. 5. Length frequency of 6,489 goldeye taken along Little Missouri Arm 1967-68.

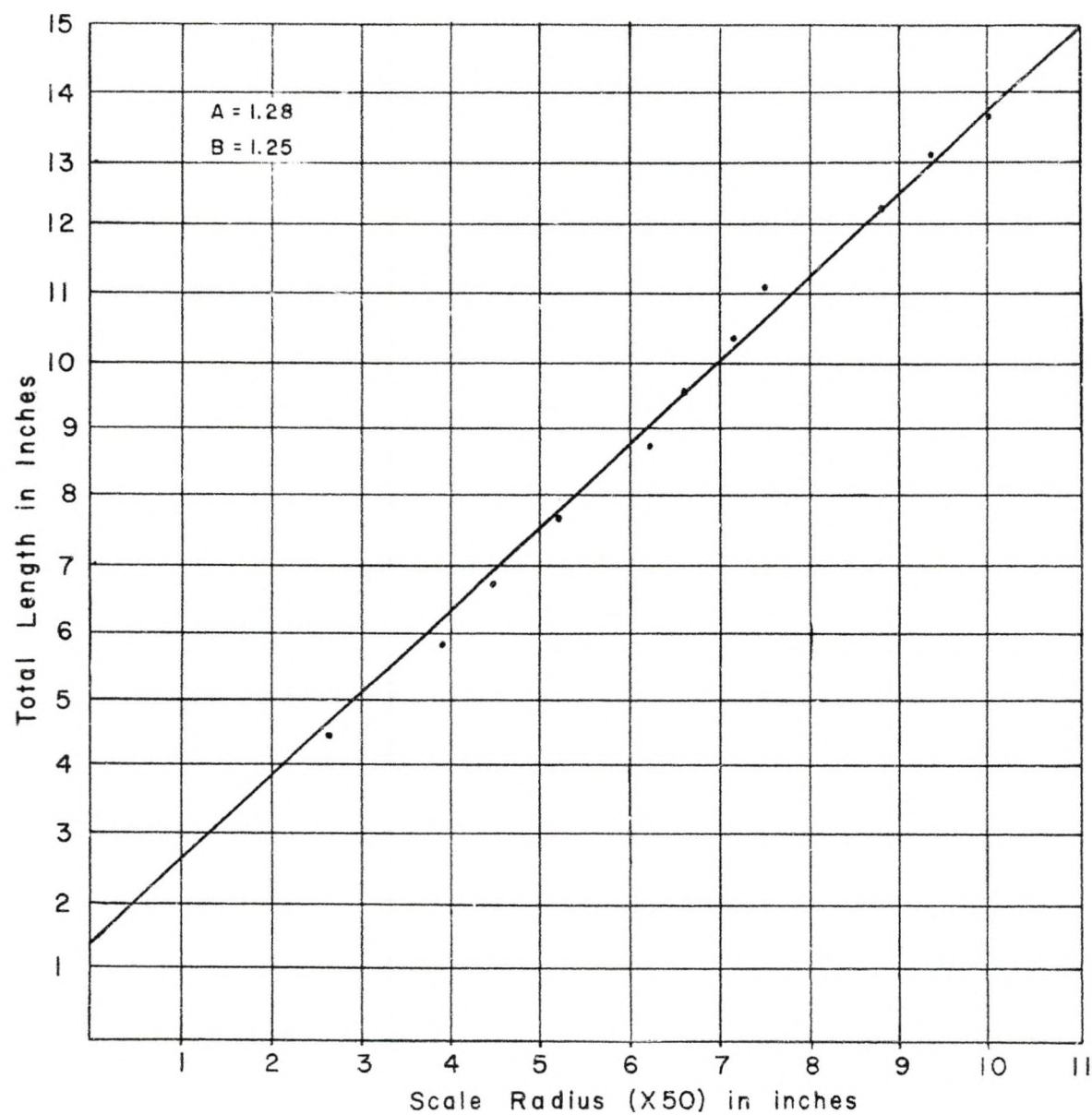


FIG. 6. Relationship between total length in inches and scale radius (x50) in inches of goldeye. Dots represent means scale radius for goldeyes in one inch size groups.

TABLE 12

AVERAGE CALCULATED TOTAL-LENGTHS AND INCREMENTS OF AVERAGE TOTAL-LENGTH FOR EACH
AGE-GROUP (SEXES COMBINED) COLLECTED IN LITTLE MISSOURI ARM, 1968

Mean Calculated Total Length (In Inches) at Annulus									
Age Group	No. Fish	Year Class	Range	I	II	III	IV	V	VI
I	30	1967	4.9-8.4	4.79					
II	115	1966	8.1-9.9	4.89	7.60				
III	132	1965	9.4-11.9	7.97	7.97	9.75			
IV	190	1964	10.0-13.1	5.15	7.92	9.73	10.81		
V	90	1963	10.6-14.6	5.26	8.05	9.63	10.75	11.44	
VI	10	1962	11.8-13.5	5.82	8.49	9.88	10.79	11.40	11.93
Total	567								
Grand Average				5.10	7.90	9.72	10.79	11.43	11.93
Mean Annual Increment				5.10	2.80	1.82	1.07	.64	.50

length of females goldeye was greater than male in every age group except group I, where both sexes were of similar length (Fig. 7).

Vertical water temperatures along the Little Missouri Arm rarely indicated a thermal stratification. Nevertheless, thermoclines were noted at stations 2, 3, 4, and 5 on July 16-31, 1967, and at stations 1, 2, and 3 on June 1-15, 1968 (Tables 25 through 34, Appendix B). Thermal stratification was preceded by several days of extremely hot and calm weather. All thermoclines were temporary and were quickly dissipated upon the resumption of prevailing winds.

The amount of dissolved oxygen varied up and down the Little Missouri Arm and ranged from 5 to 9 ppm during the summer of 1967 and 8 to 11 ppm during the spring of 1968. A reduction of more than 2 ppm dissolved oxygen from the surface to the bottom could not be measured at any station (Tables 25 through 34).

Lateral and vertical variations in turbidity levels along the Little Missouri Arm were observed and there was a gradual increase in turbidity levels from station 1 to 8 (Tables 25 through 34). Turbidity also increased with an increase in depth at each station. The identity of a distinct layer of water was not maintained for any distance along the Little Missouri Arm and convergence lines were never detected.

Depth readings at station 6 during 1968 were between 6 and 7 feet; however, vertical sampling suggested sharp differences in water quality at various depths. A sharp increase in turbidity and decrease in water temperature was noted at about the 2½ to 3 foot depth (Tables 30 through 34). The turbidity and water temperature above this layer were 56 to 182 J.T.U. and 3 to 9 degrees centigrade warmer, respectively. This turbid layer did not move and affected the catch because fish were

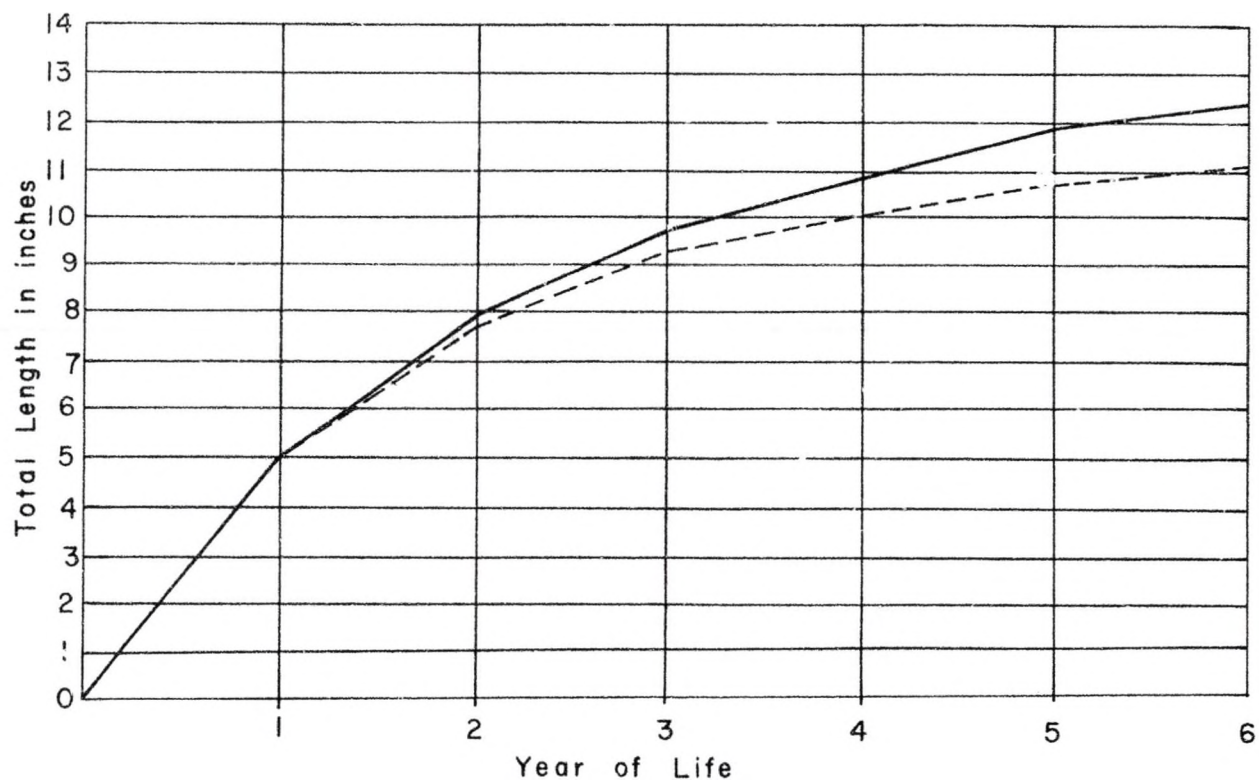


FIG. 7. Average calculated total-lengths of 527 goldeye. Solid line represents females. Broken line represents males (1968 collection).

not taken below the three foot level in the net. However, turbidity seems to increase the goldeye catch and affect sex ratio (Table 13).

TABLE 13

COMPARISON OF TURBIDITY, NUMBER GOLDEYE CAUGHT, AND GOLDEYE SEX RATIO
IN THE LITTLE MISSOURI ARM, LAKE SAKAKAWEA, 1967 AND 1968.

Station No.	*Mean Turbidity In J.T.U.	Average No. of Goldeye Caught Per Net Set	Male/Female Ratio
1	6	77	1:1.78
2	7	68	1:1.77
3	15	99	1:1.79
4	13	86	1:1.17
5	26	140	1:0.84
6	28	145	1:1.01
7	46	138	1:0.66
8	61	125	1:0.64

* Turbidity taken at 2 1/2 ft. depth (J.T.U. = ppm)

DISCUSSION AND CONCLUSIONS

It has been well established that goldeye are active near the surface during the summer months; therefore, floating gill nets were employed in this study to sample these populations. The goldeye taken during this study in 1967 and 1968 represented 90.80 percent of all species taken. In comparison, the catch in similar nets set on the bottom by the North Dakota Game and Fish Department contained 26.38 to 36.40 percent goldeye. Peterson (1967) reported that goldeye comprised 53.28 percent of the total catch taken in a vertical gill net which extended from the surface to the bottom in 50 feet of water. These percentages do not necessarily represent a true appraisal of goldeye abundance in the Little Missouri Arm; however, they may be indicative of relative populations in various strata of water.

It is unknown whether these populations can support a commercial fishery. However, the majority of the goldeye taken in this investigation weighed approximately seven ounces round weight, considerably less than the minimum dressed weight of 12 ounces desired for the commercial market (Kennedy and Sprules, 1967). Goldeye from Fort Peck Reservoir which weighed less than this minimum have been marketed in Winnipeg. However, they brought eight cents less per pound than for larger fish (Cooper, 1968). It may be that the small size of Lake Sakakawea goldeye reflects over-population or insufficient food supply. Therefore, the growth rate of these fish may be enhanced

by an increased fishing pressure which would reduce this population. Cooper (1968) reported that continuous and intensive netting in confined areas of Fort Peck reservoir drastically reduced the catch of goldeye. Therefore, the removal of greater numbers and smaller sized goldeye from the Little Missouri arm, employing small net size and considerably greater fishing effort, may ultimately produce fish large enough to bring premium prices on the commercial market. The controlled commercial fishing pressure may then be utilized as a management tool to ensure the continued production of such a goldeye fishery.

The inch class composition of the catch of goldeye taken in the summer of 1967 varied somewhat from that of the catch of the spring of 1968. More 6, 7, 8, and 9 inch fish were taken in 1967 than in 1968. Heib (1968) postulated that goldeye may school in the reservoir in classes of similar sizes. Therefore, the apparent lateral and vertical distribution of goldeye found in this study may be a reflection of this schooling behavior. However, the data collected in this investigation does not explain the mechanism involved.

The sex ratio of the catch also varied with location of capture. The ratios among fish taken at stations 1, 2, and 3 were 1:1.79 and among fish taken at stations 7 and 8, further up the arm, were 1:0.64. This imbalance in favor of males may be due to the turbidity gradient which increased with distance up the reservoir arm. Hill (1965) found that the sex ratio of goldeye taken in tributaries of the Fort Peck Reservoir were in favor of males. However, he did not equate this situation with an increase in turbidity. Martin (1952), Hill (1965), and Kennedy and Sprules (1967) reported that sex ratios were in favor

of females in the main body of lakes and reservoirs. However, Grosslein and Smith (1959) found a predominance of males in Red Lake, Minnesota, a shallow and somewhat turbid body of water. This imbalance may be the result of selective catch by commercial fisheries since female goldeye are larger than male.

Test netting in the current study in 1967 and 1968 showed a mesh selectivity. Of 3,709 goldeye taken, the $1\frac{1}{4}$ inch mesh captured the greater number, 1,327. However, the greatest average length, 11.47 inches, was recorded from fish taken with the $1\frac{1}{2}$ inch mesh. The failure of the largest mesh size, $1\frac{3}{4}$ inches, to take fish of the largest average length may be explained by the fact that goldeye frequently became entangled in the soft cord of the net by their teeth. Further investigation employing nets constructed from harder twine of smaller diameter may give a more clear picture of mesh selectivity in capturing goldeye.

It has been established that goldeye are nocturnal, surface feeders (Bajkov, 1930; Hinks, 1943; Grosslein and Smith, 1959; Peterson, 1967). Therefore, the depth preference of goldeye suggest that they are probably influenced by feeding habits and temperature. Nettings during the spring of 1968 indicate a gradual shift in depth preference from the bottom to the surface as water warmed up (Table 10). However, this shift occurred about the time that terrestrial insects emerged, indicating that food availability on the surface may have exerted a greater influence on goldeye distribution. The greater number of ripe females taken at locations having warmer water temperatures may indicate the influence of this factor on the schooling of maturing females. Cooper (1968) found that goldeye in Fort Peck Reservoir reversed their

summer preference for surface waters in the fall.

The time of annulus formation varies with the species of fish and environmental factors. Scales from goldeye captured in early May 1968 showed considerable growth between the outermost distinguishable annulus and the edge of the scale. By mid June, new annuli were evident near the edge of scales taken from all of a sample of seven fish. Although there are indications that annuli were perhaps formed in early June, further work and more detailed sampling are needed to determine the exact time of annulus formation. Data collected in this study showed that the most rapid growth of goldeye in the Little Missouri Arm occurred during July and early August. This was followed by a period of less rapid growth in late August and September and little, if any, growth between October and May.

The rate of growth of goldeye in the Little Missouri Arm appeared to be somewhat slower than that reported for this species in other geographic locations (Table 14). Growth in Lake Texoma, Oklahoma, exceeded that of goldeye from all other areas during their first two years of life. This is probably due to warmer mean annual water temperatures which occur earlier in the year and are of longer duration. This longer growing season would permit greater annual growth. Goldeye from Red Lakes have greater annual growth rates after age class II than fish from other regions. Increased water temperatures may play a role in these shallow lakes. However, goldeye samples analyzed (Grosslein and Smith, 1959) were taken from those available to commercial gear, i.e., $3\frac{1}{2}$ inch mesh, which routinely took fish over 10 inches in total length and predominately older than age class II.

Growth rates were also calculated according to sex and it was

TABLE 14

COMPARISON OF AVERAGE CALCULATED TOTAL LENGTHS OF LITTLE
MISSOURI ARM GOLDEYE WITH THOSE FROM OTHER AREAS

Mean Calculated Total Lengths (In Inches) at Annulus								
	No. Fish	I	II	III	IV	V	VI	VII
Lake Texoma, Okla. (Martin, 1952)	817	7.5	8.8	11.2	12.6	13.2	14.2	-
Red Lake, Minn. (Grosslein & Smith, 1959)	1,165	4.1	8.3	11.3	12.9	14.1	15.0	-
Missouri River, S. Dak. (Claflin, 1963)	266	4.5	7.9	10.5	11.9	12.8	13.5	-
Fort Peck, Mont. (Hill, 1965)	747	4.0	8.0	10.2	11.4	12.1	12.9	15.5
Moccasin Bay, Lake Sakakawea, N. Dak. (Heib, 196)	365	4.5	7.5	9.5	10.7	11.5	-	-
Present Study (1967-1968)	567	5.1	7.9	9.7	10.8	11.4	11.9	-

shown that females were of greater total length than males after the second year of life; six-year-old females averaged 1.2 inches longer than males of comparable age. A similar differential growth rate was reported by Martin (1952).

One of the primary objectives of this study was to determine the presence or absence of density currents along the Little Missouri Arm, Lake Sakakawea. Preliminary density current investigation on the reservoir arm by Peterson (1967) were inconclusive and provided little evidence to support the existence of such currents. However, water temperatures taken at stations 1 to 8 indicated that stratified layers were rare and never continuous from station to station. The failure to locate a sharp reduction in dissolved oxygen along the Little Missouri Arm suggests the absence of any density flow. In addition, turbid layers of water did not maintain their identity from one station to another, suggesting a gradual mixing and settling out of suspended sediment. In this respect, Bell (1942) stated that dilution is the major factor causing the destruction of turbid interflows or underflows. This occurs because dilution reduces stream velocity, allowing deposition to take place.

The amount of silt deposited by the Little Missouri River varies from 0 to 1,330,000 tons per day and between 2,000,000 and 10,000,000 tons per year (Schultz, 1968). This was determined by measuring sediment deposits on the reservoir bottom by a series of electrical soundings in a line perpendicular to the arm. Sedimentation at four locations along the Little Missouri Arm is shown in figures 3 and 8. These profiles of silt deposits show that greater rates of deposition occur in the upper end of the Little Missouri Arm, suggesting

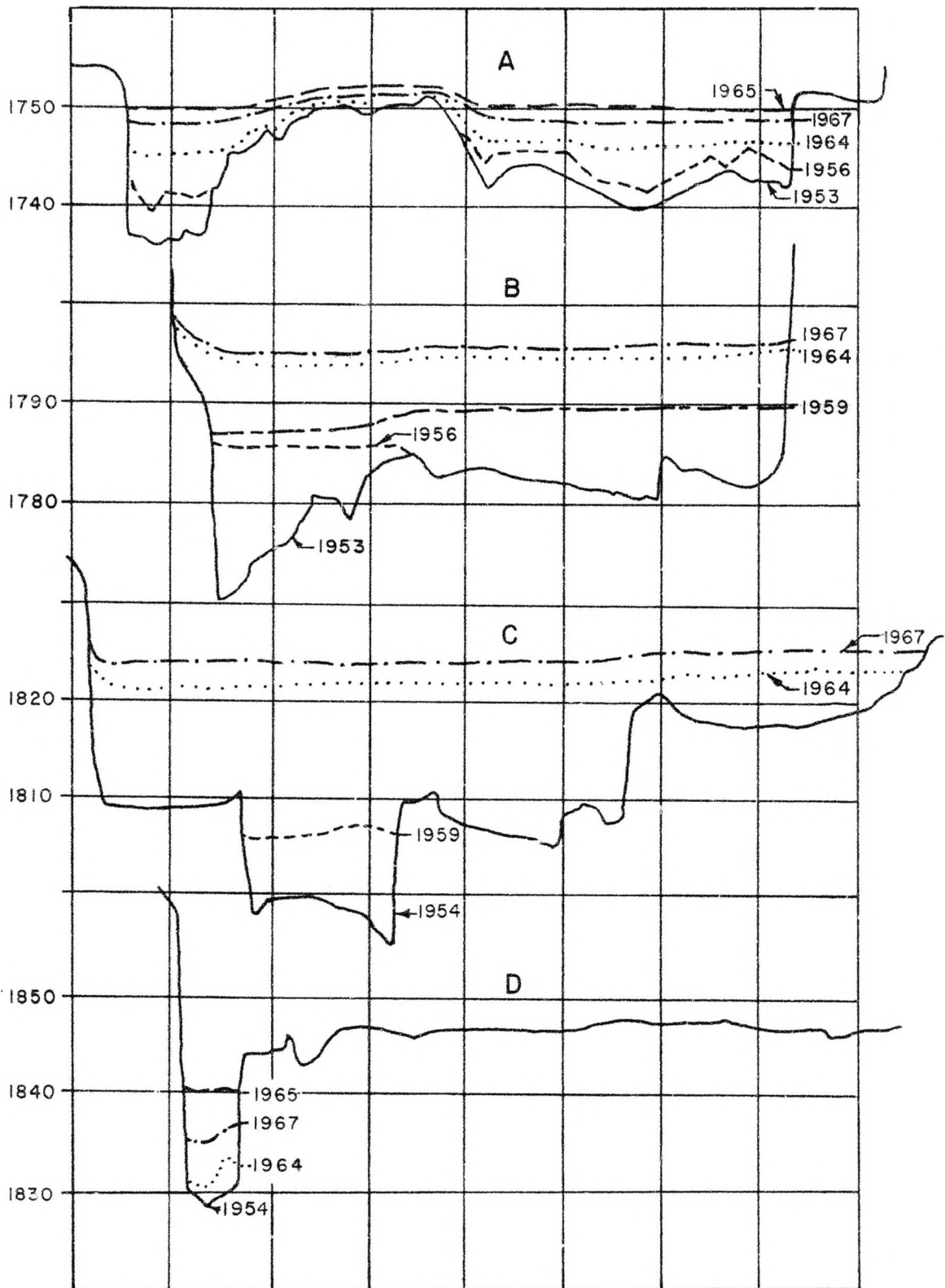


FIG. 8. Cross sections showing sediment buildup at four locations along Little Missouri Arm, Lake Sakakawea (U. S. Army Corps of Engineers).

that sediment was deposited immediately upon entering the reservoir. In as much as density currents were not detected and most sediment was deposited before reaching the confluence of the Missouri-Little Missouri River, there is little evidence to support the existence of density currents. However, temporary turbidity currents which moved along the bottom of the Arm to its confluence with the Missouri River have been reported by personnel of the Army Corps of Engineers (Schultz, personal communication, 1968).

A turbid underflow was temporarily detected at station 6 during the spring of 1968 which had readings in excess of 4,000 ppm at depths of 2 1/2 to 3 feet. Nets set at this location reflected the presence of a layer or barrier to fish at the 2 1/2 to 3 foot level, as they were not taken below this level. However, this layer did not retain its identity for any great distance as it could not be detected at station 5. This may have been moved or flushed further into the reservoir and deposited by the run-off from occasional heavy rains in the area. The presence of this underflow was substantiated by a sharp reduction in vertical water temperature and increase in turbidity. There was little movement of this layer. The convergence line reported by Peterson on August 25, 1966, may have indicated the presence of a similar turbid underflow or interflow. However, this investigation failed to detect the presence of any such convergence line.

There is very little information available on the lateral distribution of fishes in large impoundments. However, it is known that many species of fish move into shallow waters to feed during an increase in water levels. The catch of goldeye in the present study

suggested that they move and concentrate in areas of warmer water during the spring, which may indicate a definite temperature preference during the spawning season.

A comparison of turbidity with the goldeye catch showed a gradual increase from stations 1 through 8. However, it is unknown whether increased turbidity reduced the ability of fish to avoid nets, resulting in the larger catches, or whether these were just indicators of greater fish density and activity in the area.

According to Ellis (1937), turbidity is probably the principal factor limiting plankton productivity in the Missouri River. Wallen (1951) found that when fish were experimentally subjected to montmorillonite (Hydrous aluminum silicate) turbidities of 20,000 ppm they behaved abnormally and died after prolonged exposure to 175,000 to 225,000 ppm. Complete blanketing of the gills with soil materials suggested interference with oxygen intake. However, turbidities recorded under natural conditions have been somewhat below the minimal lethal turbidity in these experiments. These may range between 137 and 14,800 ppm and have been recorded in Oregon, Idaho, Texas, and South Dakota (Bennett, 1962). According to Buck (1956), turbidity of these magnitudes tend to reduce the productivity of basic food items, success of reproduction and growth rate of fishes. Further studies of the effect of turbidity on reproduction, growth, and distribution in Little Missouri Arm are necessary to more fully assess the effect of turbidity on such factors.

APPENDIX A
TABLES OF INCH CLASSES OF GOLDEYE BY STATION FOR TEN SAMPLING PERIODS

TABLE 15

INCH CLASSES OF GOLDEYE BY STATION FOR THE SAMPLING
PERIOD JULY 1-15, 1967.

Station No.	Inch Classes										
	4	5	6	7	8	9	10	11	12	13	14
1	0	0	2	8	18	4	28	36	4	0	0
2	0	0	1	12	15	9	27	32	7	0	0
3	0	0	0	11	9	3	18	23	3	0	0
4	0	0	1	7	14	5	15	19	8	0	0
5	0	0	0	26	39	27	19	27	5	0	0
6	0	0	0	34	47	21	47	39	7	1	0
7	0	0	0	10	26	6	35	42	10	0	0
8	0	0	0	2	20	2	59	63	13	1	0
Totals	0	0	4	110	188	77	248	281	57	2	0

TABLE 16

INCH CLASSES OF GOLDEYE BY STATION FOR THE SAMPLING
PERIOD JULY 16-31, 1967

Station No.	Inch Classes										
	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	6	12	6	15	23	8	0	0
2	0	0	1	13	21	0	13	23	5	1	0
3	0	0	0	9	10	1	13	30	4	0	0
4	0	0	0	4	11	0	12	10	3	0	0
5	0	0	0	12	35	17	45	38	5	0	0
6	0	0	0	48	59	14	33	22	4	0	0
7	0	0	0	12	11	4	31	42	2	0	0
8	0	0	0	0	0	0	56	60	9	1	0
Totals	0	0	1	104	159	51	218	248	40	2	0

TABLE 17

INCH CLASSES OF GOLDEYE BY STATION FOR THE SAMPLING
PERIOD AUG. 1-15, 1967.

Station No.	Inch Classes										
	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	0	3	3	16	42	8	0	0
2	0	0	0	0	5	4	25	30	5	0	0
3	0	0	0	7	44	10	15	18	5	0	0
4	0	0	0	1	17	6	26	45	4	0	0
5	0	0	0	12	60	15	42	58	7	0	0
6	0	0	3	22	71	20	35	37	6	0	0
7	2	1	0	0	3	1	16	45	5	0	0
8	1	0	0	0	1	4	33	71	9	0	0
Totals	3	1	3	42	204	63	208	346	49	0	0

TABLE 18

INCH CLASSES OF GOLDEYE BY STATION FOR THE SAMPLING
PERIOD AUG. 16-31, 1967.

Station No.	Inch Classes										
	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	0	10	11	19	42	16	1	0
2	0	0	0	2	7	7	12	15	2	1	0
3	0	0	0	2	21	13	13	27	11	0	0
4	0	0	1	2	23	16	20	10	1	0	0
5	0	0	0	2	13	8	21	24	4	0	0
6	1	1	1	2	38	11	25	29	5	0	0
7	0	0	0	2	23	15	57	73	12	2	0
8	0	0	0	0	5	6	25	81	8	1	0
Totals	1	1	2	12	140	87	192	301	59	5	0

TABLE 19

INCH CLASSES OF GOLDEYE BY STATION FOR THE SAMPLING
PERIOD SEPT. 1-15, 1967.

Station No.	Inch Classes										
	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	1	9	6	9	35	4	0	0
2	0	0	1	0	6	8	15	36	12	1	0
3	0	0	0	3	19	15	20	27	12	0	0
4	0	0	0	3	13	15	12	33	6	0	0
5	0	0	1	1	13	10	24	35	5	0	0
6	0	0	0	0	7	9	26	30	10	0	0
7	0	0	0	8	41	30	42	71	24	2	0
8	0	0	0	0	4	3	26	69	15	0	0
Totals	0	0	2	16	112	96	174	336	88	3	0

TABLE 20

INCH CLASSES OF GOLDEYE BY STATION FOR THE SAMPLING
PERIOD APRIL 15-30, 1968.

Station No.	Inch Classes										
	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	0	0	0	0	0	1	0	0
2	0	0	0	0	0	0	0	2	1	0	0
3	0	0	0	0	0	1	0	4	2	0	0
4	0	0	0	0	0	2	8	12	8	2	0
5	0	0	0	0	0	1	8	25	11	0	0
6	0	0	0	0	0	0	0	13	6	0	0
Totals	0	0	0	0	0	4	16	56	29	2	0

TABLE 21

INCH CLASSES OF GOLDEYE BY STATION FOR THE SAMPLING
PERIOD MAY 1-15, 1968.

Station No.	Inch Classes										
	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	0	0	0	6	21	8	2	0
2	0	0	0	0	0	0	11	31	16	1	0
3	0	0	0	0	2	1	3	12	5	0	0
4	0	0	0	0	0	3	10	40	9	1	0
5	0	0	0	0	1	0	24	124	31	3	1
6	0	0	0	0	0	0	2	24	3	0	0
Totals	0	0	0	0	3	4	56	252	72	7	1

TABLE 22

INCH CLASSES OF GOLDEYE BY STATION FOR THE SAMPLING
PERIOD MAY 16-30, 1968.

Station No.	Inch Classes										
	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	0	0	1	4	25	14	1	0
2	0	0	0	0	0	1	8	40	13	1	1
3	0	0	0	1	0	6	9	30	16	2	0
4	0	0	0	0	1	1	18	103	34	3	1
5	0	0	0	0	0	1	19	94	43	4	0
6	0	0	0	0	0	0	10	80	23	2	0
Totals	0	0	0	1	1	10	68	372	143	13	2

TABLE 23

INCH CLASSES OF GOLDEYE BY STATION FOR THE SAMPLING
PERIOD JUNE 1-15, 1968.

Station No.	Inch Classes										
	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	0	0	3	7	27	13	1	0
2	0	0	0	0	0	0	0	2	0	0	0
3	0	0	1	0	0	1	9	41	7	0	0
4	0	0	0	0	0	2	27	88	30	1	0
5	0	0		0	2	4	33	92	32	2	0
6	0	0	0	0	0	0	12	31	15	3	0
Totals	0	0	1	0	2	10	88	281	97	7	0

TABLE 24

INCH CLASSES OF GOLDEYE BY STATION FOR THE SAMPLING
PERIOD JUNE 16-30, 1968.

Station No.	Inch Classes										
	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	0	1	1	5	14	5	1	0
2	0	0	0	0	1	0	5	13	6	2	0
3	1	0	1	0	0	2	15	58	15	0	0
4	2	0	0	2	3	7	29	76	17	1	0
5	0	0	0	1	0	0	28	146	47	5	0
6	0	0	0	0	0	0	5	25	14	1	0
Totals	3	0	1	3	5	10	87	332	104	10	0

APPENDIX B
VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS
FOR TEN SAMPLING PERIODS

TABLE 25

VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS FOR
SAMPLING PERIOD JULY 1-15, 1967

Temperatures at Each Station (in Degrees Centigrade)

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	20.0	21.0	21.5	22.0	23.0	23.0	25.0	25.0
7.5 "	19.5	21.0	21.5	22.0	23.0	23.0	24.5	24.5
12.5 "	19.5	21.0	21.5	22.0	22.5	23.0	24.5	
17.5 "	19.0	21.5	20.5	21.5	22.0			
22.5 "	19.0	20.5	20.5	21.5				
27.5 "	19.0	20.5	20.5	21.0				
32.5 "	19.0	20.5	20.5					
37.5 "	19.0	20.0	20.5					
42.5 "	18.5	20.0						
47.5 "	18.5							

Turbidity at Each Station in J.T.U.

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	0	4	8	20	32	40	42	62
7.5 "	4	4	6	18	36	44	48	170
12.5 "	4	4	10	16	40	48	54	
17.5 "	6	8	10	24	52			
22.5 "	4	8	10	30				
27.5 "	6	12	12	32				
32.5 "	8	10	16					
37.5 "	8	14	18					
42.5 "	10	16						
47.5 "	12							

Dissolved Oxygen at Each Station in p.p.m.

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	7.0	7.0	7.0	8.0	7.0	7.0	8.0	8.0
7.5 "	7.0	7.0	7.0	8.0	7.0	7.0	8.0	8.0
12.5 "	7.0	7.0	7.0	8.0	7.0	7.0	7.0	
17.5 "	7.0	7.0	7.0	7.0	7.0			
22.5 "	7.0	7.0	7.0	7.0				
27.5 "	7.0	7.0	7.0	7.0				
32.5 "	7.0	7.0	7.0					
37.5 "	7.0	7.0	7.0					
42.5 "	7.0	7.0						
47.5 "	7.0							

TABLE 26

VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS FOR
SAMPLING PERIOD JULY 16-31, 1967

Temperatures at Each Station (in Degrees Centigrade)								
Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	22.0	23.0	23.0	22.5	23.5	24.0	26.5	26.0
7.5 "	21.5	21.0	23.0	22.5	23.0	24.0	24.5	24.0
12.5 "	21.0	20.5	20.5	20.5	21.5	23.5	23.5	
17.5 "	20.5	19.5	20.0	20.0	20.0			
22.5 "	19.5	19.5	20.0	19.0				
27.5 "	19.0	17.0	20.0					
32.5 "	18.5	16.5	20.0					
37.5 "	17.5	16.5	20.0					
42.5 "	17.0	16.0						
47.5 "	17.0							

Turbidity at Each Station in J.T.U.								
Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	0	8	5	12	30	38	38	58
7.5 "	8	8	4	12	36	46	43	142
12.5 "	6	10	5	14	38	40	58	
17.5 "	4	10	6	14	50			
22.5 "	6	14	6	16				
27.5 "	9	16	8	24				
32.5 "	8	15	8					
37.5 "	8	16	10					
42.5 "	12	24						
47.5 "	14							

Dissolved Oxygen at Each Station in p.p.m.								
Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	7.0	9.0	8.0	8.0	7.0	6.0	9.0	9.0
7.5 "	7.0	9.0	8.0	8.0	7.0	7.0	7.0	8.0
12.5 "	7.0	8.0	8.0	8.0	6.0	7.0	6.0	
17.5 "	7.0	8.0	7.0	7.0	5.0			
22.5 "	7.0	8.0	7.0	7.0				
27.5 "	7.0	8.0	7.0	7.0				
32.5 "	7.0	8.0	7.0					
37.5 "	7.2	7.0	7.0					
42.5 "	7.0	7.0						
47.5 "	7.2							

TABLE 27

VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS FOR
SAMPLING PERIOD AUG. 1-15, 1967

Temperatures at Each Station (in Degrees Centigrade)

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	20.5	22.5	22.0	22.0	22.0	23.0	21.0	20.0
7.5 "	20.5	22.5	21.5	22.0	21.5	22.0	20.5	20.0
12.5 "	20.5	20.5	21.0	21.5	21.5	21.5	20.5	
17.5 "	20.5	20.5	21.0	21.5	21.0			
22.5 "	20.5	20.5	21.0	21.0				
27.5 "	20.5	20.5	21.0	20.5				
32.5 "	20.5	20.5	20.5					
37.5 "	20.5	20.5	20.0					
42.5 "	20.0	20.0						
47.5 "	18.5							

Turbidity at Each Station in J.T.U.

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	6	6	5	14	32	34	60	58
7.5 "	10	8	10	18	35	36	62	70
12.5 "	18	9	12	16	32	42	62	
17.5 "	17	6	12	22	35			
22.5 "	17	10	14	26				
27.5 "	18	18	15	32				
32.5 "	20	18	14					
37.5 "	19	20	16					
42.5 "	19	22						
47.5 "	20							

Dissolved Oxygen at Each Station in p.p.m.

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
7.5 "	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
12.5 "	7.0	7.0	7.0	7.0	7.0	7.0	7.0	
17.5 "	7.0	7.0	7.0	7.0	8.0			
22.5 "	7.0	7.0	7.0	7.0				
27.5 "	7.0	7.0	7.0	7.0				
32.5 "	7.0	7.0	7.0					
37.5 "	7.0	7.0	7.0					
42.5 "	7.0	7.0						
47.5 "	7.0							

TABLE 28

VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS FOR
SAMPLING PERIOD AUG. 16-31, 1967

Temperatures at Each Station (in Degrees Centigrade)

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	20.5	21.5	22.0	22.0	22.0	22.0	22.0	21.5
7.5 "	20.5	21.0	21.5	22.0	22.0	22.0	22.0	21.5
12.5 "	20.5	20.5	21.0	21.0	22.0	21.5	21.5	
17.5 "	20.5	20.5	21.0	21.0	21.5			
22.5 "	20.5	20.5	21.0	21.0				
27.5 "	20.5	20.5	21.0	20.5				
32.5 "	20.5	20.5	21.0					
37.5 "	20.5	20.5	21.0					
42.5 "	20.5	20.5						
47.5 "	20.0							

Turbidity at Each Station in J.T.U.

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	3	4	7	12	16	18	44	64
7.5 "	4	6	6	14	32	32	45	74
12.5 "	10	15	6	18	40	46	52	
17.5 "	6	16	10	20	42			
22.5 "	10	16	10	24				
27.5 "	11	18	12	24				
32.5 "	12	20	20					
37.5 "	14	20	24					
42.5 "	14	22						
47.5 "	16							

Dissolved Oxygen at Each Station in p.p.m.

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	7.4	7.2	8.0	7.0	7.2	7.0	7.0	7.4
7.5 "	7.4	7.2	8.0	7.0	7.2	7.0	7.0	7.0
12.5 "	7.4	7.2	7.8	7.0	7.0	7.0	6.8	
17.5 "	7.4	7.2	7.8	7.0	7.0			
22.5 "	7.2	7.2	7.8	7.0				
27.5 "	7.2	7.0	7.4	6.8				
32.5 "	7.2	7.0	7.2					
37.5 "	7.2	7.0	7.0					
42.5 "	7.2	7.0						
47.5 "	7.2							

TABLE 29

VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS FOR
SAMPLING PERIOD SEPT. 1-15, 1967

Temperatures at Each Station (in Degrees Centigrade)

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	20.0	20.0	21.5	22.0	20.5	21.0	20.0	19.5
7.5 "	20.0	20.0	21.0	21.0	20.5	20.0	20.0	19.5
12.5 "	20.0	20.0	20.5	20.5	20.0	19.5	20.0	
17.5 "	20.0	20.0	20.5	20.5	19.5			
22.5 "	19.5	20.0	20.5	20.0				
27.5 "	19.5	19.5	20.5	20.0				
32.5 "	19.5	19.5	20.0					
37.5 "	19.5	19.5	20.0					
42.5 "	19.5	19.5						
47.5 "	19.0							

Turbidity at Each Station in J.T.U.

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	12	10	4	14	25	24	42	60
7.5 "	10	12	5	12	30	26	52	68
12.5 "	10	12	6	12	36	45	60	
17.5 "	10	12	6	16	46			
22.5 "	10	10	8	16				
27.5 "	12	12	10	18				
32.5 "	10	10	10					
37.5 "	10	10	12					
42.5 "	12	14						
47.5 "	14							

Dissolved Oxygen at Each Station in p.p.m.

Depths	#1	#2	#3	#4	#5	#6	#7	#8
2.5 ft.	7.0	7.0	7.0	7.0	8.0	7.0	7.0	8.0
7.5 "	7.0	7.0	7.0	7.0	8.0	7.0	7.0	8.0
12.5 "	7.0	7.0	7.0	7.0	7.5	7.0	7.0	
17.5 "	7.0	7.0	7.0	7.0	7.0			
22.5 "	7.0	7.0	7.0	7.0				
27.5 "	7.0	7.0	7.0	7.0				
32.5 "	7.0	7.0	7.0					
37.5 "	7.0	7.0	7.0					
42.5 "	7.0	7.0						
47.5 "	7.0							

TABLE 30

VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS FOR
SAMPLING PERIOD APRIL 16-30, 1968

Temperatures at Each Station (in Degrees Centigrade)

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	3.0	4.0	4.5	6.0	8.0	8.0
7.5 "	3.0	3.5	4.0	6.0	7.5	
12.5 "	3.0	3.0	4.0	6.0		4 ft.-5.0°
17.5 "	3.0	3.0	4.0	6.0		
22.5 "	3.0	3.0	4.0			
27.5 "	3.0	3.0	4.0			
32.5 "	3.0	3.0				
37.5 "	3.0	3.0				
42.5 "	3.0					
47.5 "						

Turbidity at Each Station in J.T.U.

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	6	8	26	54	58	155
7.5 "	6	8	28	60	60	
12.5 "	6	8	30	60		4 ft.>4000
17.5 "	8	7	30	62		
22.5 "	10	6	30			
27.5 "	10	8	32			
32.5 "	12	10				
37.5 "	16	10				
42.5 "	18					
47.5 "						

Dissolved Oxygen at Each Station in p.p.m.

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	11	11	10	10	10	11
7.5 "	11	11	10	10	10	
12.5 "	11	11	10	10		
17.5 "	11	11	10	10		
22.5 "	11	11	10			
27.5 "	11	11	10			
32.5 "	11	11				
37.5 "	11	11				
42.5 "	11					
47.5 "						

TABLE 31

VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS FOR
SAMPLING PERIOD MAY 1-15, 1968

Temperatures at Each Station (in Degrees Centigrade)

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	5.5	6.0	7.0	8.0	8.0	5.5
7.5 "	5.5	6.0	7.0	8.0	7.5	
12.5 "	5.5	6.0	7.0	8.0		1 ft.-9°
17.5 "	5.5	6.0	7.0	8.0		2 ft.-9°
22.5 "	5.5	6.0	7.0			
27.5 "	5.5	6.0	7.0			
32.5 "	5.5	6.0				
37.5 "	5.5	6.0				
42.5 "	5.5					
47.5 "						

Turbidity at Each Station in J.T.U.

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	15	22	35	75	62	182
7.5 "	10	22	38	85	62	
12.5 "	10	22	32	90		3.5 ft.-7400
17.5 "	10	32	36	95		
22.5 "	0	30	34			
27.5 "	5	28	36			
32.5 "	7	32				
37.5 "	7	34				
42.5 "	0					
47.5 "						

Dissolved Oxygen at Each Station in p.p.m.

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	11	10	10	10	10	10
7.5 "	11	10	10	10	10	
12.5 "	11	10	10	10		
17.5 "	11	10	10	10		
22.5 "	11	10	10			
27.5 "	11	10	10			
32.5 "	11	10				
37.5 "	11	10				
42.5 "	11					
47.5 "						

TABLE 32

VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS FOR
SAMPLING PERIOD MAY 16-31, 1968

Temperatures at Each Station (in Degrees Centigrade)

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	7.0	8.0	9	11	11	16.5
7.5 "	7.0	7.5	9	11	10	
12.5 "	7.0	7.5	9	11		5 ft.-7.0°
17.5 "	7.0	7.5	9	11		
22.5 "	7.0	7.5	9			
27.5 "	7.5	7.5	9			
32.5 "	7.0	7.5				
37.5 "	6.5	7.5				
42.5 "	6.5					
47.5 "						

Turbidity at Each Station in J.T.U.

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	14	20	20	60	33	56
7.5 "	16	22	24	66	7200	
12.5 "	15	24	26	68		3 ft.>4000
17.5 "	14	25	20	72		
22.5 "	16	25	28			
27.5 "	16	25	30			
32.5 "	16	26				
37.5 "	18	30				
42.5 "	20					
47.5 "						

Dissolved Oxygen at Each Station in p.p.m.

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	10	10	9	9	10	10
7.5 "	10	10	9	9	11	
12.5 "	10	10	9	9		
17.5 "	10	10	9	9		
22.5 "	10	10	9			
27.5 "	10	10	9			
32.5 "	10	10				
37.5 "	10	10				
42.5 "	10					
47.5 "						

TABLE 33

VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS FOR
SAMPLING PERIOD JUNE 1-15, 1968

Temperatures at Each Station (in Degrees Centigrade)						
Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	18.5	15.0	16.5	14.5	15.0	14.0
7.5 "	13.0	12.5	15.5	14.5	15.0	
12.5 "	11.5	12.5	14.0	14.5		
17.5 "	11.0	10.0	13.5	14.5		
22.5 "	10.0	9.5	13.0			
27.5 "	9.5	9.0	13.0			
32.5 "	9.0	8.5				
37.5 "	8.5	8.0				
42.5 "	8.0					
47.5 "						

Turbidity at Each Station in J.T.U.						
Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	2	14	15	40	95	>4000
7.5 "	0	16	18	43	98	
12.5 "	0	11	26	45		
17.5 "	0	17	20	46		
22.5 "	0	13	22			
27.5 "	2	16	24			
32.5 "	0	15				
37.5 "	0	14				
42.5 "	0					
47.5 "						

Dissolved Oxygen at Each Station in p.p.m.						
Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	10	10	9	9	8	8
7.5 "	10	10	9	9	8	
12.5 "	10	10	9	9		
17.5 "	10	10	9	9		
22.5 "	10	11	10			
27.5 "	10	11	10			
32.5 "	10	11				
37.5 "	10	11				
42.5 "	10					
47.5 "						

TABLE 34

VERTICAL WATER TEMPERATURE, DISSOLVED OXYGEN, AND TURBIDITY READINGS FOR
SAMPLING PERIOD JUNE 16-30, 1968

Temperatures at Each Station (in Degrees Centigrade)

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	14.5	13.5	16.0	18.0	17.5	15.5
7.5 "	14.0	13.5	15.5	18.0	17.0	
12.5 "	13.5	13.0	15.0	17.0		Surface-19.0
17.5 "	13.0	13.0	14.5	16.5		3 ft.-16.5°
22.5 "	11.5	13.0	14.0			7.5 ft.-14.0°
27.5 "	11.5	12.0	13.0			
32.5 "	11.5	12.0				
37.5 "	11.5	11.5				
42.5 "	11.5					
47.5 "						

Turbidity at Each Station in J.T.U.

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	0	0	20	24	70	180
7.5 "	0	0	20	30	70	
12.5 "	0	0	20	30		3 ft.>4000
17.5 "	0	0	20	30		
22.5 "	0	0	20			
27.5 "	0	0	25			
32.5 "	0	0				
37.5 "	2	0				
42.5 "	4					
47.5 "						

Dissolved Oxygen at Each Station in p.p.m.

Depths	#1	#2	#3	#4	#5	#6
2.5 ft.	9	9	9	9	8	8
7.5 "	9	9	9	9	8	
12.5 "	9	9	9	9		
17.5 "	9	9	9	9		
22.5 "	9	9	9			
27.5 "	9	9	9			
32.5 "	9	9				
37.5 "	9	9				
42.5 "	9					
47.5 "						

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